CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-101

November 5, 1980

1. Name of Faults

Richmond segment

Hayward fault (~~north of University of California~~), and Wildcat fault of Bishop (1973).

2. Location of Fault

Contra Costa and Alameda Counties, Richmond and Mare Island 7.5 minute quadrangles (see Figure 1).

3. Reason for Evaluation

Part of 10-year program to evaluate and revise Alquist-Priolo Special Studies Zones maps (see Hart, 1980) (see Figure 2A&B).

4. List of References*

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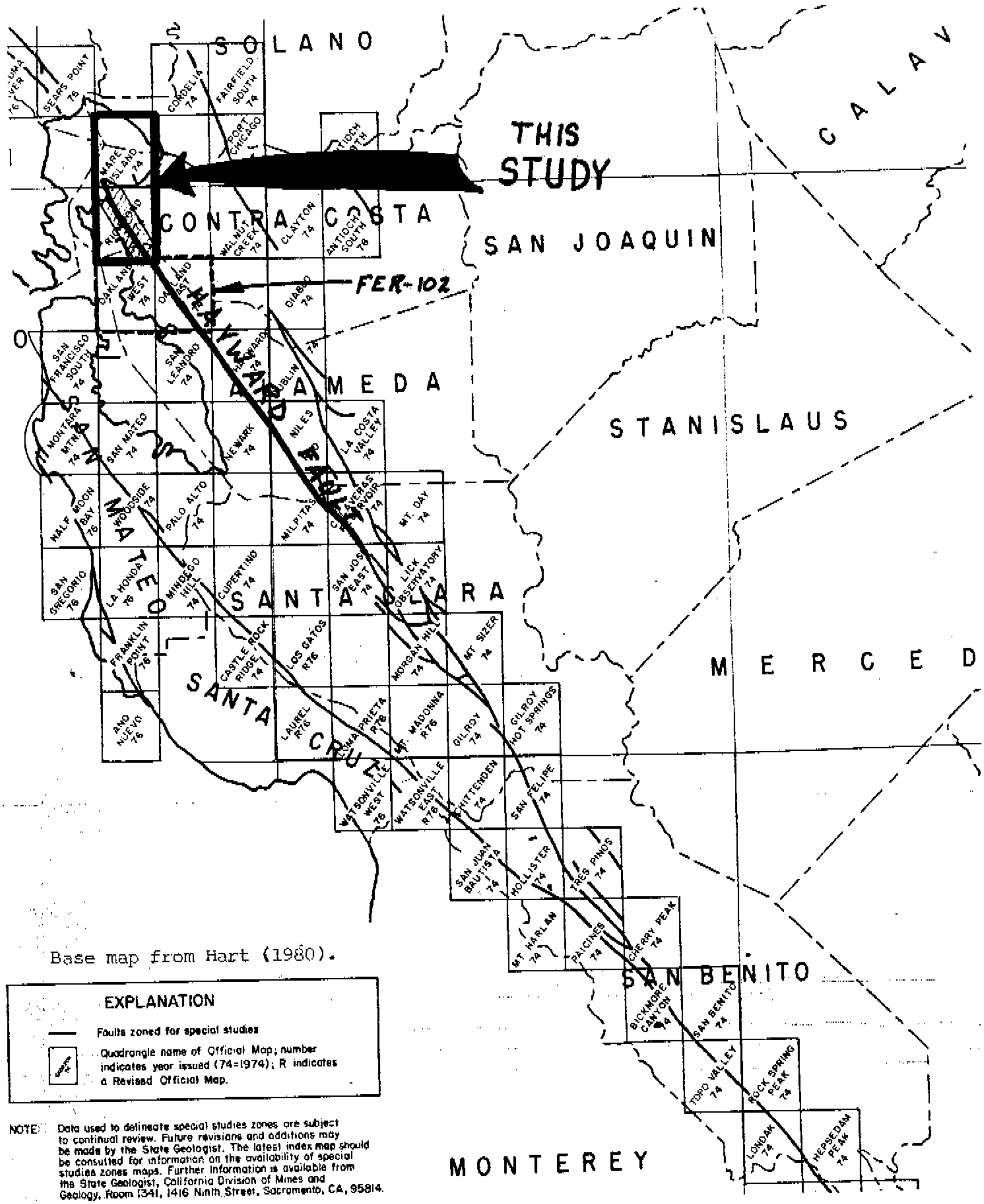
Bishop, C.C., Knox, R.H., Chapman, D.A., Rodgers, and Chase, G.B., 1973, Geological and geophysical investigations for Tri-cities Seismic Safety

* References cited include supplements or amendments to the cited reports, and review comments by the local jurisdiction's geologist. Also included are Alquist-Priolo file numbers (e.g., AP#1008) and informal consulting report file numbers (e.g., C#327) assigned by CDMG.

Figure 1. Location of Mare Island and Richmond quadrangles.



Base map from Hart (1980).

EXPLANATION

— Faults zoned for special studies

Quadrangle name of Official Map; number indicates year issued (74=1974); R indicates a Revised Official Map.

NOTE: Data used to delineate special studies zones are subject to continual review. Future revisions and additions may be made by the State Geologist. The latest index map should be consulted for information on the availability of special studies zones maps. Further information is available from the State Geologist, California Division of Mines and Geology, Room 1341, 1416 Ninth Street, Sacramento, CA, 95814.

Scale 1:1,000,000

1 inch equals approximately 16 miles

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5. Summary of Available Data

The Hayward fault is principally a right-lateral, strike-slip fault which extends from Point Pinole Regional Shoreline southward towards Milpitas (Radbruch, 1968). Part of the San Andreas fault system, the connection of the Hayward with the Calaveras, and eventually, the San Andreas, has puzzled many for years.

Lawson and others (1908, p. 434) reported that surface rupture occurred along the Hayward fault in 1868. This zone of rupture extended from near Warm

Springs, in the south, to the vicinity of Mills College in Oakland, "...but the evidence of its existence to the northward of San Leandro is not very satisfactory." Displacement of 8 to 10 inches was generally reported, with a maximum displacement of 3 feet in Hayward. Louderback (1947, p. 43) concluded, based on a news item in the Oakland Daily News (Nov. 10, 1868), that another earthquake during June 1836 was accompanied by surface rupture along the Hayward. This article indicates that "there were large fissures in the earth [in 1868]..." and that "...the [1868] phenomena appear to be a repetition of those observed in 1836, and noted by persons residing in the valley." The 1836 event was felt from San Pablo to Mission San Jose. Based on Louderback's paper, Jennings (1975) depicted the 1836 rupture as extending from Point Pinole to Mission San Jose.

The Lawson and others (1908) study of the 1868 earthquake was undertaken almost 40 years after the 1868 earthquake occurred. They were unable to determine the sense of displacement that occurred during the 1868 event. In 1926, Russell described the offset streams, sag ponds and other fault-produced features along the Hayward. He concluded (p. 511) that the sense of displacement was right-lateral, and that "...in the main the displacement has been slow and by small steps...", but that larger, 1868-like events had also occurred. Buwalda (1929), after describing briefly the evidence for vertical (eastern block up, relatively) displacement along the Hayward fault (largely called upon to explain the physical positions of younger and older formations on either side of the fault zone), concluded that the most recent displacements have been almost entirely strike-slip. He cites, as evidence against major, recent, vertical movement, the elevation of an offset alluvial deposit, once a shutter ridge (now obliterated) which sits at an elevation equal to that of Hamilton

Gulch (south of UC Berkeley) which he concluded was its source. He also describes horizontal slickensides in the Lawson Adit (located on the UC campus). More recent surveys directed at detecting tectonic creep along the Hayward have confirmed that right-lateral, strike-slip movement is occurring along the Hayward (Nason, 1971; Radbruch, 1968; and others).

Buwalda's description of the Lawson Adit, located just east of the Mining Building, includes an interesting description of part of the Hayward fault zone. According to Buwalda, the adit was driven about 200 feet into the fault zone, encountering gouge, breccia, and "...intermingled blocks of sandstone and rhyolite."

> "In the roof of the tunnel nearly horizontal gravels lie across the eroded edges of the nearly vertical slices and bands of gouge. While exposures are somewhat limited, the surface on which the gravels lie appears to be nearly flat. <u>Of the vertical fault surfaces seen none apparently passes up into the gravels</u>." (p. 197, underlining added for emphasis).

Buwalda concluded that these gravels are deposits from Strawberry Creek which have been right-laterally offset along an active fault trace. He does not indicate, however, that the adit completely crossed the fault zone. According to data in Lennert and Curtis (1980), the adit did not cross the active trace.

Case (1963) described several topographic features indicative of right-lateral, strike-slip faulting along the Hayward. He concluded that, based on the straightness of the mapped traces, the fault plane must be steep to vertical in the Berkeley Hills area. He notes, however, "Nowhere within (his) mapped area has the fault plane been observed."

In 1966, several articles reporting fault creep on the Hayward were published. Radbruch and Lennert (1966a; 1966b) reported on damage to a culvert constructed in 1923 beneath Memorial Stadium, located about 1/4 mile south of the Richmond quadrangle. They reported (1966b) that damage was first detected in 1948 and was repaired at that time. Further damage was detected in 1965. They (1966a) calculated a slip rate of 0.11 inch (0.28 cm) per year at this site. Bolt and Marion (1966) described their efforts to detect fault creep on the campus using creepmeters. However, their monitoring data covered only the limited period of October 1965 to January 1966-not really long enough to do more than confirm that fault creep probably was occurring during that period.

Radbruch (1967) made the first real attempt at a comprehensive study of the Hayward fault. Her 1967 map was largely a compilation of the results of the efforts of other workers. In the Richmond quadrangle, this included only Case (1963), supplemented with her own field work and air photo interpretation. The scale (1:62,500) of the 1967 map lacked much of the detail of her (1968) 1:24,000 scale version. The latter map is annotated with limited descriptions of fault-produced topography and other data. She cites that fault creep has occurred disrupting two streets in Parchester Village and on Fordham Way (see Figure 2). However, it is apparent from this study that she made little or no effort to delete from her maps those fault traces del~~me~~ in eated by other workers which either probably did not exist or which were not active.

Nason (1971) reported evidence for fault creep on Phanor, Banks and Thomas Drives (in Parchester Village), on the Contra Costa College campus, and on Fordham, Arundel and Bowhill southeast of the CCC campus. Based on the amount of distortion and the ages of the various improvements, Nason calculated that fault creep was occurring at a rate of about 0.55 cm/year at these sites.

In 1973, Bishop, et al., completed a geologic report covering the cities of San Pablo, El Cerrito, and Richmond. Included was a map of active faults (Bishop, 1973), annotated and similar to Radbruch's (1968) map. Bishop's fault traces differed from Radbruch's in detail, but, with one exception, were fairly similar. Bishop considered part of the Wildcat Canyon Parkway and associated cracks in the pavement. Also cited was the linear drainage of Wildcat Creek, and a deflected drainage northeast of the Mira Vista Country Club. ? Bishop's (1973) fault data are summarized on Figure 3. Bishop (p. c., 1980) has re-examined the Wildcat Canyon Parkway site since publication of the report, and has concluded that the distress observed was probably not the result of fault creep.

During the compilations of the Special Studies Zone Maps (California Division of Mines and Geology, 1974a; 1974b; included in this report as Figure 2), Hart (the project supervisor) and the compiler (T.C. Smith) discussed whether to depict the traces of only one or more of the existing publications. It was decided that since Bishop, et al., (1973) was the latest available publication and since they had available to them all the earlier released work of the other authors, Bishop's (1973) version should be used within the Tri-cities study area and Radbruch's (1968) version used elsewhere. In any case, the SSZ boundaries encompassed the areas where traces of the Hayward where shown by either author.

On the Richmond SSZ map, (see Figure 2A), a "C" symbol is shown along the Hayward fault in Kensington. The original compilation mylars are no longer in the A-P file, and the source of this supposed creep evidence is unknown. None of the publications used to prepare the 1974 SSZ map nor any reviewed during this study refer to creep in this location. And the author (who prepared the original map) does not recall any creep being cited by any person in this vicinity.

After the SSZ maps were issued, Radbruch-Hall (1974) published an updated version of her Radbruch(1968) map. On this version, an additional fault trace was depicted; and along this trace, at Marin Avenue, Berkeley, she notes that a street and sidewalk are distorted"...due to landsliding, fault movement, or both." She also noted an exposure of fault gouge at Berryman Reservoir along this trace. A second, shorter fault trace is also shown at the reservoir. Most of these two traces lie outside the present SSZ boundary. Radbruch-Hall did not delineate landslide masses in the Berkeley Hills, but she does refer to active landslides in several annotations. Her (1974) fault traces are shown on Figure 3.

In 1978, Herd completed a map of the northern Hayward fault zone. Based mostly on the interpretation of 1939 black and white, large-scale aerial photographs (U.S. Department of Agriculture, 1939), Herd's version depicts fault-produced topographic features. With the exception of references to fault creep in the Parchester Village area, Herd's version makes no reference to the work of others. Herd's data are summarized in Figure 3. While Herd depicts recent landslides, he does not, for the most part, depict features which could be fault produced that lie within the landslide areas. At Point Pinole, Herd departs significantly from earlier workers by depicting a fault trace, on land, within the Mare Island quadrangle. This trace, a few hundred feet northeast of those depicted by Bishop (1973) and Radbruch-Hall (1974), also lies outside the 1974 SSZ.

The remaining sources of data cited herein are all unpublished consulting reports, mostly completed in compliance with the SSZ Act (see Hart, 1980). These reports are indexed by number on Figure 3. If significant original work utilizing definative methods (e.g., trenching) was a part of the investigation, then the results are discussed. Other reports are noted on the map and tabulated in Table 1. Of the investigations referenced, five included trenches that could conceivably have crossed fault traces depicted on Figures 2, 3, or 6.

Terrasearch, Inc. (1977, with 1978 addendum, map reference AP 713) excavated a 400-foot long trench which appears to have crossed one of Radbruch-Hall's (1974) approximately located traces. No evidence of faulting of the soil and alluvial deposits was detected.

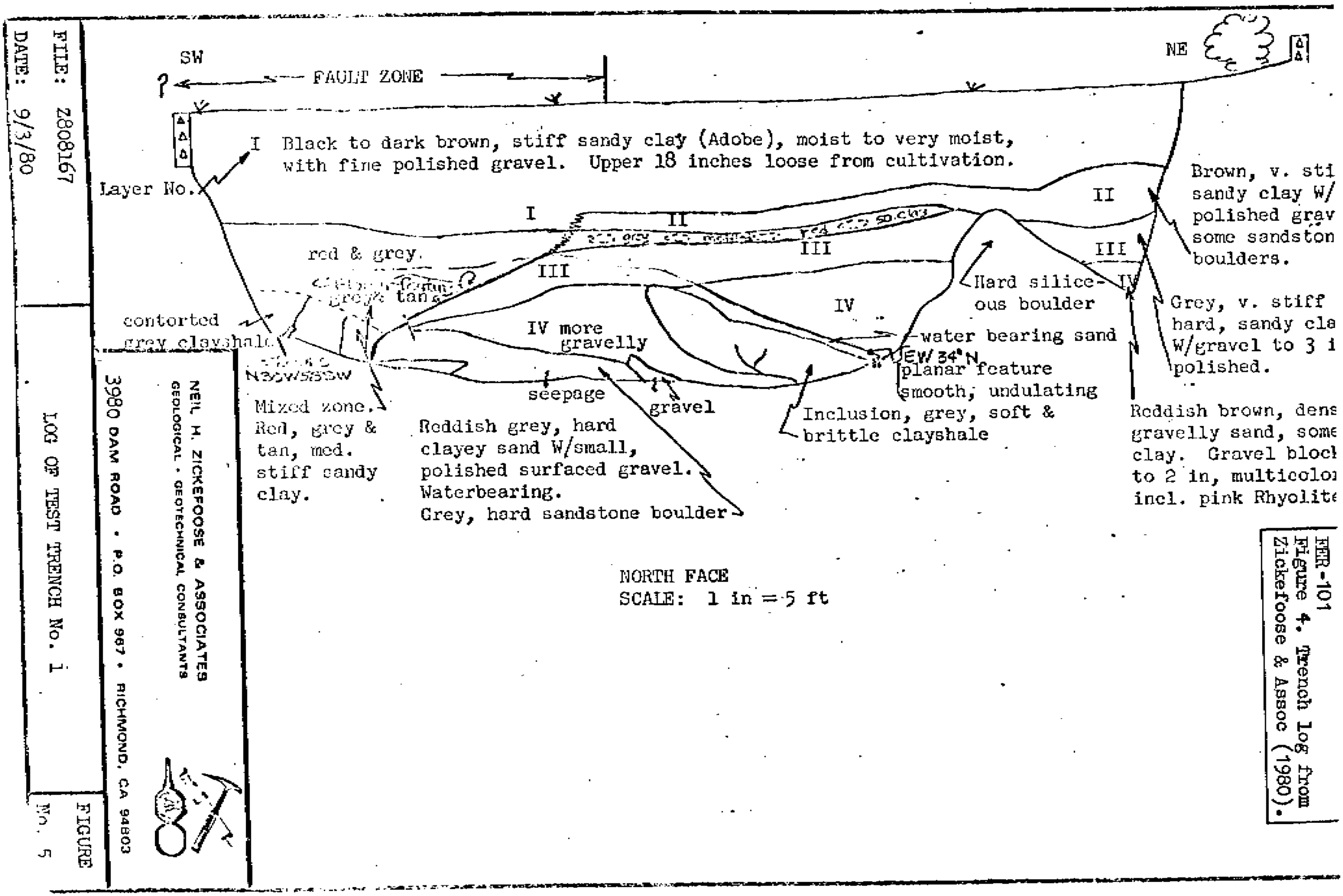
Earth Sciences Associates (1977a, map reference AP 557; 1977b, map reference AP 566) and Soares and Associates (1980, map reference AP 1186) all appear to have trenched across or near several fault traces (see Figure 3). Neither consultant detected any active faults in the trenches excavated, but both indicated an active fault passed just east of the ends of the trenches. At both of ESA's sites, the trenches were excavated in well-bedded alluvium.

Woodward-Clyde Consultants (1978, map reference AP 727) excavated several trenches in an effort to detect active fault traces. Two trenches were excavated across Bishop's (1973) Wildcat fault. WCC failed to detect any through-going fault as depicted by Bishop. They did, however, intersect active faults in six trenches, and identified two, relatively narrow, active fault zones. Their report, however, was part of a local planning effort, and their investigation was intended only to provide a refined version of the SSZ map. Also, Herd (1978) and Smith (this report) determined that much of the site was a landslide mass, including the area where the faults were found. They concluded that Radbruch-Hall's (1974) fault traces were valid, while Bishop's traces were not found as he shows them. Unfortunately, their map does not show the two active zones identified, but instead only shows air photo lineaments. Engeo, Inc. (1977a, map reference AP 445) covers a parcel within the redevelopment area investigated by WCC, and detected no shear zones in their trench.

Zickefoose and Associates (1980, map reference C377) detected what they determined to be a Holocene or historic fault in an area of recent landsliding. They could not, however, detect any through-going air photo lineaments on the site. The trench logs, reproduced here as Figures 4 and 5, document anomalous conditions along a Case (1963) fault.

Harding-Lawson Associates (1974, map reference C168) investigated the Cragmont School site, adjacent to Radbruch-Hall's (1974) Marin Avenue creep locality. They reported that a linear crack was present in the playground surface, extending from the corner of Marin Avenue and Spruce Street northeastward through the site toward Regal Road. They report this crack is the northern limit of a large, slow-moving landslide (the Euclid Landslide) and that the crack through the playground has existed for over 12 years. Estimates of horizontal landslide movement prior to the paving of the school yard have been as high as one inch per year.

Harding, Miller, Lawson & Associates (1972a, map reference C444), detected two faults in bedrock on the Contra Costa College campus. No young units were present above the bedrock, however, the trend and location of the faults was



FER-101
Figure 4. Trench log from Zickefoose & Assoc (1980).

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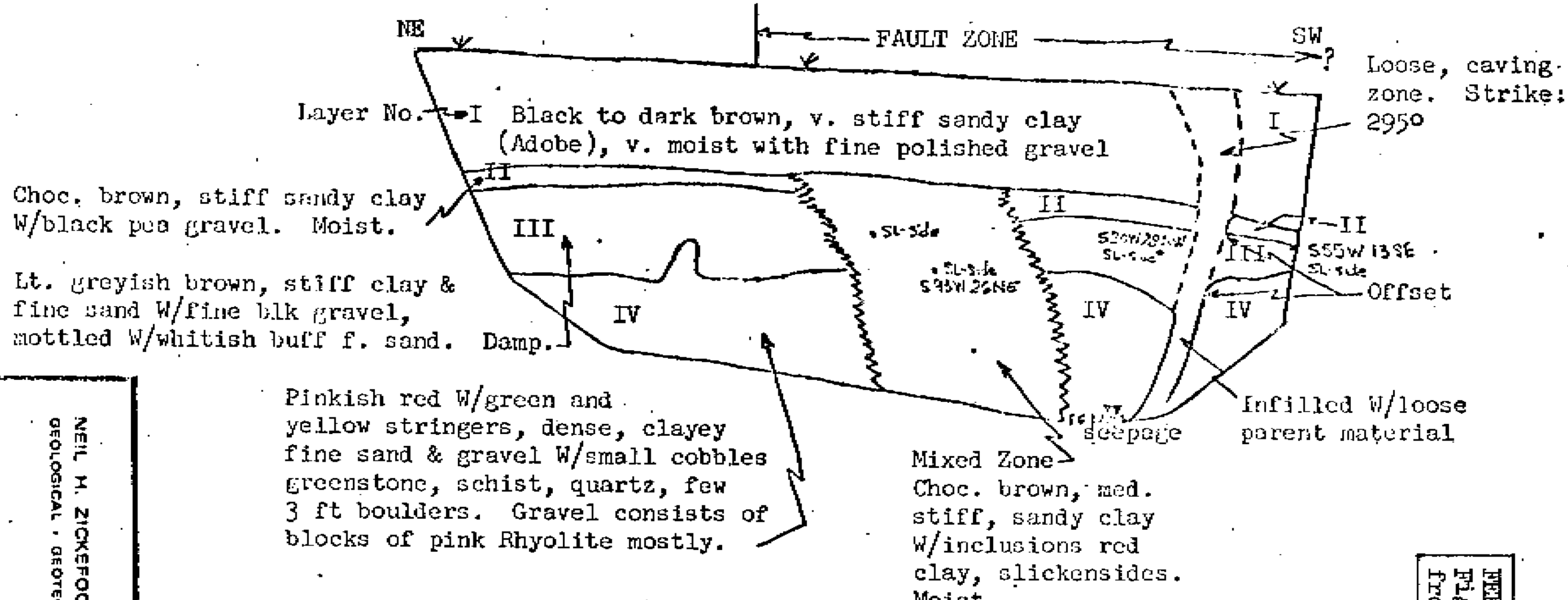

SOUTH FACE
SCALE: 1 in = 5 ft

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LOG OF TEST TRENCH No. 2

FIGURE

FER-101
Figure 5. Trench log reproduced from Zickefoose & Assoc (1980).

close enough to the Hayward that they considered these traces to be active. The other reports in the series report on other parts of the campus where faults were found, but determined not to be active.

In summary, the literature documents the possible existence of active fault traces outside the SSZ established in 1974 near Pinole Point and in the City of Berkeley. Also, some fault traces shown by Radbruch-Hall (1974, and earlier versions) and Bishop (1973) apparently do not exist or are not active (e.g., the Wildcat fault). Observations by Buwalda (1929) in the Lawson Adit suggest that the Louderback trace of Radbruch-Hall does not disrupt alluvial deposits which may be pre-Holocene in whole or in part. And, Herd (1978) failed to detect any features indicative of Holocene faulting along the western traces of Case (1963) which pass near Mira Vista School (in Richmond) and The Circle (in Berkeley), although recent landsliding could have disrupted the topography sufficiently that even highly active, Holocene faults would be difficult to detect. See item 6 for a further discussion of these topics.

6. Interpretation of Aerial Photographs; Field Observations

Aerial photographs were interpreted and various sites were field checked by the author in an effort to resolve conflicting reports concerning the existence of various active fault traces. Specifically field checked were localities where evidence for fault creep has beed reported. When vertified, an effort was made to detect additional evidence for fault creep in the vicinity.

In parts of the Richmond and Mare Island quadrangles, the Hayward fault trace is fairly well-defined by linear scarps, deflected drainages, shutter ridges, sag ponds and other geomorphic features associated with active right-

TABLE 2. Description of Evidence for Fault Creep in the Richmond Quadrangle (refer to Figure 7).

R-1 U.S. Geological Survey San Pablo Alignment Array, installed in 1966, shows offset between monuments SPAA 9 and SPAA 12. (Observations made without the benefit of surveying instruments.)

R-2 Curbs on both sides of Banks Drive are right-laterally offset in front of #612 and #613. The street has been patched several times between the two curbs, indicating problems with underground utilities periodically occurring (B+ quality).

R-3 Curb and sidewalk in front of #704 Phanor Drive is offset right-laterally, and the driveway is badly broken. The driveway, walk and curb in front of #705 has been replaced, but the curb between #701 and #705 shows a distinct right-lateral bend. The driveway pavements of both #701 and #705 ~~is~~ are slightly broken. The east wall of #704 shows an obvious bend. Left-stepping, en echelon fractures (2 orders) are present in the street pavement in line with the curb offsets (A quality).

R-4 The south curb in front of #712 Thomas Drive is right-laterally offset; sidewalk blocks are rotated clockwise; and there is a sag in the adjacent pavement. The driveways of #712 and #800 are resisting the ground movement, appearing to have been pushed out into the street; the concrete sections in these driveways do appear to be rotated clockwise. In front of #713, the north curb and sidewalk are right-laterally offset. Some left-stepping, en echelon fractures were observed adjacent to the north curb, but are roughly parallel to the street, not the trend of the fault. A fence between #709 and #713 appears to be slack and may be right-laterally offset (A quality).

R-5 The house at #801 Payne Court is being pulled apart. The northwest wall of the house has been pulled away from the foundation as evidenced by an opening in the garage slab (B quality).

R-6 In front of and just east of #809 Payne Drive, the north curb and sidewalk is distorted. Cracks between the sidewalk and curb sections indicate extension. Right-laterally offset curb located about two feet east of driveway. A concrete gutter on the east side of the driveway is severely broken. The south curb and sidewalk ~~is~~ are broken by tree roots, and pushed up about one foot into the air; however, a right-lateral offset was apparent in the driveway (behind 4213 McGlothen) (B quality).

R-7 Driveway in front of #4201(?) McGlothen Way appears to have been replaced, but the new pavement was poured with a right-lateral jog on the north edge. Driveway in front of #4205 shows a definite right-

see page 23 for quality definitions.

lateral bend. The curb and sidewalk on the northwest corner of McGlothen and Bradford Drive are rotated and buckled slightly, with minor spalling of the concrete curb. The concrete gutter across McGlothen shows a definite right-lateral bend, and left-stepping en echelon fractures were observed about 2-1/2 feet north of the point of offset, trending toward the offset. The southwest corner of the intersection also is distorted, with left-stepping, en echelon fractures in the pavement passing about 3 feet east of the curb. The curb in front of #4116 McGlothen is right-laterally offset, indicating the zone of disturbance may be as wide as 20 feet here. The driveways in front of #4112 and #4108 are right-laterally offset (A quality).

R-8 Sag in an old fence on trend with scarp (C quality).

R-9 Narrow (15 inches wide) zone of left-stepping, en echelon fractures in asphalt pavement in front of #1416 Miner Avenue. Curb in front of #1416, #1500 and #1510 (west side) show clockwise rotation and extension. Driveways of these three homes are very broken. The curb between #1415 and #1409 is rotated clockwise and has been extended. Two small brick walls between #1409 and #1401 are distorted, one appears to be right-laterally offset, the other may be affected by nontectonic pressures. Curbs on the east side of the street northward to #1310 show some evidence of extension (B+ quality).

R-10 The south curb and sidewalk between #1906 and #1910 Miner Avenue are right-laterally offset; extension is indicated by open cracks between sections of sidewalk. Likewise, the curb between #1901 and #1907 is right-laterally offset. There is a zone of left-stepping, en echelon fractures in the street pavement in front of #1906 and #1907 on trend with the offset of the curbs. The garage wall of #1901 shows a distinct right-lateral bend, and the driveway has been partly repaved (A quality).

R-11 The foundation and driveway of #1925 Wanlass are very broken as are the curb and street gutter in front. The driveway appears to be "pushed" out into the street. The driveway of #1929 is broken up, and the garage door frame is badly racked out of plumb. The public sidewalk in front also shows evidence of clockwise rotation. The sidewalk in front of #2998 - 20th Street is spalled, and cracks are evident around the windows of the house. Street pavement is very coarse-no crack pattern observed (B quality).

R-12 Curb about 100 feet northwest of the fountain (Contra Costa College) on the east corner of the bus loop and the road leading to the Vocational Arts Building shows evidence of rotation and extension, but the structural integrity of the curb is preventing clean displacement. The curb on the other side of the Vocational Arts access road is spalled (indicating compression) and out of alignment. A creek adjacent, and now partly buried under a parking lot, has a ~~is deflected~~ right-laterally bend (deflected drainage ?) about 20 feet away from these points (B quality).

R-13 Unmortared brick pavement around fountain is slightly undulating and shows compression (roughly N-S direction). The sidewalk near the southeast corner has been cut with a saw, and the saw-cut has been right-laterally offset along a joint near the end of the cut (B quality).

R-14 Curb in parking lot shows evidence of east-west extension and a slight, right-lateral offset (curb does not appear in the WRD photos [U.S.G.S., 1966]). On the east side of a campus access road, the curb and a fence between the CCC campus and El Portal School are offset right-laterally (B quality).

R-15 El Portal School. A narrow zone of left-stepping, en echelon fractures (4 orders observed) is present near the northwest (rear) corner of what is probably a large multi-purpose room. The sidewalk near the front door is right-laterally offset and rotated clockwise, The west wall also appears to be rotated clockwise, as indicated by a zone of cracks extending from a window in the south wall to the southwest corner of the building where an offset of several inches is apparent. It appears the roof is still attached to the main structure, but the foundation of the west wall is being pulled away. On trend to the south, two sidewalks are rotated and right-laterally offset. Newer, wedge-shaped pieces of concrete have been installed to fill gaps in each walk (A quality).

R-16 The east fence behind El Portal School near the southeast corner of the schoolyard appears to be right-laterally offset. (C quality). (Two sags in the fence are present further north, but show no offset).

Note on background "noise" in the area of R-17 to R-20: In this development, low rolling curbs were installed. In walking around the area, it was commonplace to see cars and trucks parked on the curbs and sidewalks. Thus, many walks and curbs were depressed or broken.

R-17 In front of #2437 Bancroft Lane, the west curb and sidewalk appears to be offset right-laterally, and there is a sag in the walk. A private sidewalk in front of #2438 appears to be right-laterally offset, and the foundation of the house is cracked. Distortion was apparent at various places along the west curb between #2437 and #2455 (C quality).

R-18 The north curb of Bowhill Lane in front of #2775 is right-laterally offset several inches, and left-stepping, en echelon fractures were noted in the street adjacent. The south curb has been replaced along with the driveways of #2772 and #2778 (B+ quality).

R-19 The west curb of Fordham Drive may be right-laterally offset between

#2411 and #2409, but is not clearly so. Sag in gutter and walk, but several tire tracks noted on curb and walk. First reported by Nason (1971) (C quality).

R-20 Adjacent to 2800 Arundel Way, the south curb is deformed. Curb appears to br rotated clockwise, but was constructed on a slight bend in the street. Extension is indicated by 1+ inch gap between curb sections (B quality).

R-21 At the end of Hearst Avenue, three left-stepping en echelon fractures in the pavement (C quality). No curbs present.

Table 1 (cont).

CDMG FILE NUMBER	AUTHOR & DATE	METHODS USED: Trenching	Seismic Refraction	Other Methods*	Air Photo Interpretation	Visit Site	Literature Review	Was active fault found?	Comments
AP 733	Engeo, 1977b	XX		M, TP	XX	XX	XX	No	Found faults in outcrop; no active faults found.
AP 763	Engeo, 1978b	XX		BH	XX	XX	XX	No	
AP 791	Soares & Assoc, 1977			BH	XX	XX	XX	No	Contains a "map of distress" showing possible creep damage nearby.
AP 838	Engeo, 1978a	XX		M	XX	XX	XX	No	
AP 997	Foundation Engineers, 1979	XX				XX	XX	No	On site of AP 727.
AP 1023	Earth Sciences Assoc, 1978						XX	No	Adjacent to AP 245.
AP 1186	Soares & Assoc, 1980	XX		BH	XX	XX	XX	No	Fault likely to be adjacent to east boundary of site. Offset curb reported.
C 166	Hallenbeck-McKay, 1976				XX	XX	XX	No	
C 167	Berry, 1974					XX	XX	No	
C 168	Harding-Lawson, 1974						XX	No	Reports landslide damage (see text).
C 169	Hallenbeck-McKay, 1975b				XX	XX	XX	No	
C 377	Zickefoose & Assoc, 1980	XX			XX	XX	XX	Yes	See text. No through-going air photo lineaments noted.
C444	Harding, Miller, Lawson & Assoc 1973ab	XX		BH	XX	XX	XX	Yes not definitive	Shallow bedrock encountered, no young units found. Both active & inactive faults found.

*M= magnetometer; G= gravity; BH= bore hole correlation; TP= test pits

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Table 1. Summary of results of consultants' investigations.

CDMG FILE NUMBER	AUTHOR & DATE	METHODS USED: Trenching	Seismic Refraction	Other Methods*	Air Photo Interpretation	Visit Site	Literature Review	Was active fault found?	Comments
AP 17	Engeo, 1974		XX	BH	XX	XX	XX	No	
AP 22	Zickefoose & Assoc, 1974	limited		M	XX	XX	XX	No	Four, very short "test ditches" excavated.
AP 245	Earth Sciences Assoc, 1976				XX	XX	XX	Yes (not definitive)	Site covered by 10 to 28 ft of fill; airphotos & lit. used to locate fault.
AP 328	Engeo, 1976a	XX			XX	XX	XX	No	
AP 331	Engeo, 1976b		XX	BH	XX	XX	XX	No	
AP 350	Hallenbeck-McKay, 1975a				XX	XX	XX	No	Reports RL offset of curb & displaced staircase near cor of Southampton & Santa Barbara
AP 408	Hallenbeck-McKay, 1977				XX	XX	XX	No	Cites linear breakage in front of 277 & 273 Amhearst; bedrock exposed on site.
AP 445	Engeo, 1977a	XX	XX		XX	XX	XX	No	No active faults detected; shear zones detected in trenching operation.
AP 557	Earth Sciences Assoc, 1977a	XX			XX	XX	XX	No	Treches in well-bedded alluvial deposits.
AP 566	Earth Sciences Assoc, 1977b	XX			XX	XX	XX	No	Active fault reported likely to exist at NE corner of site. Well-bedded alluvium.
AP 629	Zickefoose & Assoc, 1977	XX			XX	XX	XX	No	Evidence of landsliding exposed in trench.
AP 713	Terrasearch, 1977	XX	XX	BH	XX	XX	XX	No	
AP 727	Woodward-Clyde, 1978	XX		BH, TP	XX	XX	XX	Yes (2)	See text.

*M= magnetometer; G= gravity; BH= bore hole correlation; TP= test pits lateral faults (see Figure 6). In some locations, clear evidence of continuing fault creep are present, as well (see Table 2 and Figure 7). However, much of the area between UC Berkeley on the south and Camp Herms on the north, as well as a few smaller areas even farther north, has been subjected to large-scale landsliding. During the field reconnaissance, some evidence of continuing landslide movement was noted. One of the major difficulties encountered was distinguishing landslide-produced features from fault-produced topography. Features such as sag ponds, scarps, and offset drainages can be produced by either landslide or fault movement. Even left-stepping, en echelon cracks in pavement and right-laterally offset curbs can be produced along the right margin of a landslide block or even within the landslide area. Thus, care must be exercised in determining whether or not such features are produced by faulting, in part or in whole.

At the same time, one must not be too quick in assuming that displaced curbs and cracked pavement and foundations in areas mapped as landslides are all landslide caused. When distress is noted, the area around the locality must be carefully checked in order to determine the probable cause. During this study, in the area just north of the UC campus, several zones of distress were noted. While some of these zones appear to be well-defined, linear (frequently curvilinear) zones of deformation, they frequently either have a significant vertical component or lack clear signs of right-lateral movement. Attributed to landslide movement, the abundance of these disturbed areas (some of which are shown on Figure 7) makes it difficult, if not impossible, to detect fault creep in several areas.

For ease of discussion, the fault data are addressed in three groups or north or NNW?

segments - the north~~west~~ern segment (northwest of St. Joseph's cemetary); the central segment (Camp Herms to St. Joseph's cemetary); and the southern segment (Camp Herms to UC campus). Briefly, the northern segment is typified by fault creep in an alluviated area; the central segment is typified by a fairly well-defined line of topographic features but lacking evidence of fault creep; and, the southern segment is typified by large landslides and down-slope movement that obscure both geomorphic and fault creep evidence.

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The Northern Segment

Clear evidence for fault creep is present in many places in the northern segment. Four A quality* sites were located in this segment. Two of these were located in Parchester Village (see Figure 6, 7? sites R-3 and R-7), another o~~f~~n Miner Avenue (R-10), and a fourth at El Portal School (R-15). These sites are fully described in Table 2. Most often these sites coincide with the geomorphic features depicted by Herd (1978) or Smith's air photo map (this report, Figure 6), or the faults shown by Radbruch (1974) or Bishop (1973). However, none of these

* The quality ratings consider the level certainty, type and magnitude (relative to background "noise") of the fault creep data. "A" quality sites are those where virtually all man-made features show the effects of fault creep, and two or more types of evidence (e.g., offset curbs and left-stepping en echelon fractures in pavement) support fault creep. "B" quality sites are those where one or more of the above factors is absent. For example, a site where one curb is offset, some en echelon fractures are observed, but the other curb is not offset would be a "B" quality site. "C" quality site are those where only one line of evidence is present. For example, a locality having one offset curb (if the offset is significantly larger than the back-ground "noise") would be a "C" quality site.

references show fault traces through every valid creep locality.

It appears that in the vicinity of Rollingwood Drive, fault creep is "stepping over" from one trace to another. In this area, a low hill was noted on U.S.D.A. (1939) photographs (see Figure 6) suggesting that a pressure ridge was forming in the alluvial plain.

All the fault creep localities verified lie within the present SSZ (CDMG, 1974b). However, the air photo data developed (Figure 6) supports the work of Herd (1978) north of Parchester Village, strongly suggesting that the Hayward fault extends (on land) into the Mare Island quadrangle.

The Central Segment

The central segment is characterized by a narrow zone of fault-produced topography (see Figure 6). The connection of this zone with the northern segment is obscured by landslides that are still moving, at least in part. Field checking of the many streets in this hill area for evidence of fault creep failed to find any damage that could not reasonably be attributed to non-tectonic causes.

Case (1963) shows two faults in this segment. Other authors (Radbruch-Hall, 1974; Bishop, 1973) have followed Case's lead and have depicted two fault strands, also. The geomorphically well-defined trace is the eastern trace. The western trace lacks through-going, well-defined features indicative of recent faulting. Instead, the terrain has a hummocky, Franciscan-like appearance suggesting that the few minor, discontinous features present (such as saddles, notches and breaks in slope) might well be the product of differential weathering or downslope movement. Therefore, the features are not definitive with respect to recency of faulting or even the presence of an old fault.

The Southern Segment

Mapping of the Hayward fault in the southern segment is made extremely difficult by massive landslides, many of which are still active. Most authors agree that the fault is probably a single strand in the area just south of and near Camp Herms. However, various interpretations exist as to the location of the fault further to the south in the landslide area. Case's (1963) trace generally follows the toes of the large landslide masses south of The Circle. Radbruch-Hall's (1974) eastern trace appears to have been drawn with a straight edge to connect three data points. The central point, on Marin Avenue near Cragment School, was carefully examined. As noted earlier, Radbruch-Hall reported that either fault creep, landslide movement or both was causing damage in the area. An examination of the area was made by Smith, and later by Smith and Hart, and it appears the damage is most probably the result of landslide movement. In fact, it may well be that some of the 17-inch "displacement" reported by Lennert and Curtis (1979) was actually the result of the curb being constructed with a slight bend. In any case, one can argue that the zone of major disturbance does not trend along or parallel to Radbruch-Hall's trace; driveways, sidewalks, and curbs on the southwest side of Santa Barbara Avenue are disturbed enough that, if fault creep were the cause, the zone would have to be delineated as trending almost due south to account for the damage.

The area from Camp Herms to UC was examined closely for any evidence of fault creep. Much damage to curbs, streets and buildings was found, but often a significant vertical (downslope) component was evident. The magnitude and pattern of all damage detected was consistent with what one would expect from landslide movement. In general, the damage occurred in broad, non-linear zones, although arcuate zones of damage was noted along the toes of some of the slide masses. Indeed, the magnitude and quantity of the landslide damage would most likely mask any fault creep evidence, if fault creep could indeed propogate through presently the moving landslide masses.

Herd (1978) chose to not show any possible fault traces in the landslide area. Interpretation of aerial photographs revealed that some features that could be the result of recent fault movement do exist; however, these features are much less well-defined than those in the central segment. The "softening" or partial obliteration of sharp, micro-topographic features would be expected to occur in an area of current landslide movement.

Urbanization is another process adding to the obliteration of fault-produced topographic features. Indeed, no exposures exist (in the urban area) that would allow one to discredit any of the faults referenced given the time allotted for the completion of this study. Indeed, in all likelihood it would be impossible to disprove the existence of an active fault along any postulated trace (even one drawn in a random fashion) even with extensive field work and excavation since datable, recent, stratigraphic horizons are lacking in this area. However, no geomorphic evidence was found to indicate the Case (1963) or Louderback traces shown by Radbruch-Hall (1974) are active or through-going faults.

<u>The "Wildcat fault"</u>

As noted earlier, Bishop (1973) depicted part of the Wildcat fault as active based on the linear course of Wildcat Creek, one possible offset stream, and a possible creep site. True, Wildcat Creek has a generally linear course, however, most tributary streams and drainages, and intermediate ridge spurs, lack any evidence of offset. As noted earlier, Bishop (p.c.) revisited the site of the

EARTHQUAKE EPICENTERS 1900-1974

OF A QUALITY ACCORDING TO CATALOG SOURCE
EARTHQUAKE CATALOG EDITION I
CALIFORNIA DIVISION OF MINES AND GEOLOGY

TRANSVERSE MERCATOR PROJECTION

SCALE = 1/250000

MAGNITUDE

..... 0.0 TO 0.9
..... 1.0 TO 1.9
..... 2.0 TO 2.9
..... 3.0 TO 3.9
..... 4.0 TO 4.9
..... 5.0 TO 5.9

0 4 8 miles
0 5 10 kilometers
SCALE

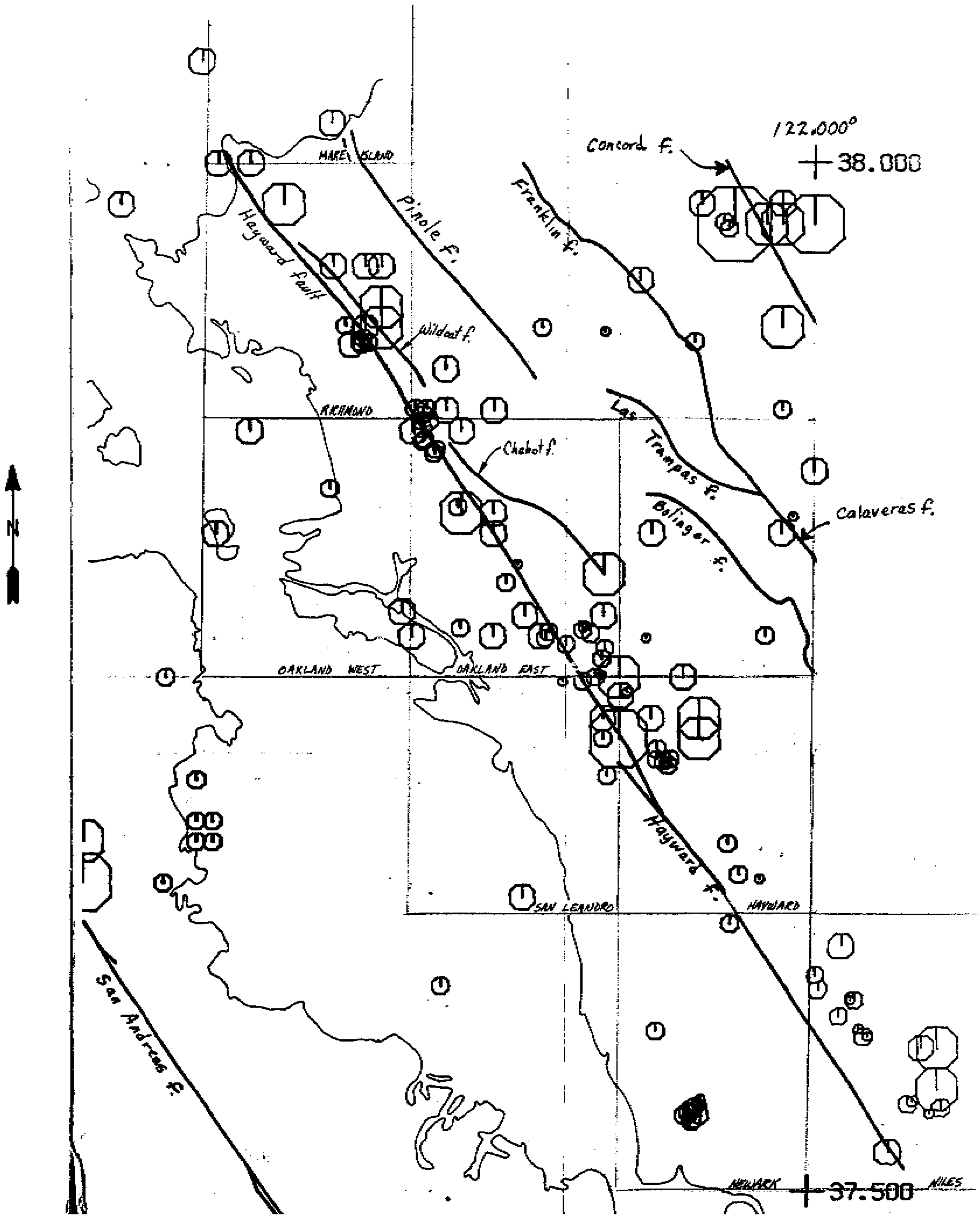

Figure 8. Locations of "A" quality earthquake epicenters in the vicinity of the Hayward fault from Point San Pablo to Niles (after Real, et al., 1978) and principal faults in the area.

postulated fault creep and has concluded that fault creep is not occurring. Smith (this report) also examined the site and concurs.

7. Seismicity

The Hayward fault has long been documented as seismically active. As noted earlier, major earthquakes occurred in 1868 (Lawson, and others, 1980) and 1836 (Louderback, 1947). Real, et al. (1978, see Figure 7) have documented a zone of seismicity along the Hayward fault. Most of the epicenters are calculated to lie on or slightly east of the trace of the Hayward as shown on most maps.

8. Conclusions.

That the Hayward fault is seismically active has been demonstrated. The literature also provides sufficiently detailed descriptions to document surface fault movement during 1868 (Lawson and others, 1908) and fault creep in some areas (Nason, 1971; Radbruch-Hall, 1974). However, investigators differ on just where the active traces of the Hayward fault are located, and how many such traces exist in the study area.

Certainly, the documented creeping traces are active. And, it appears that in the vicinity of Rollingwood Drive, either the creeping trace is not a straight line or that fault creep is "stepping over" from one trace to another. Thus, as has been documented in the Hayward area (Nason, 1971), more than one creeping fault can exist in an area. One cannot assume that the creeping faults include all of the active traces, however. Through interpretation of aerial photographs, several probable active fault traces have been identified based on recent geomorphic features generally associated with active faults. Most of the creep sites lie along those traces as shown by Herd (1978) or Smith (this report).

As noted earlier, previous workers (Radbruch, 1968; Radbruch-Hall, 1974; Bishop, 1973) have relied heavily on the work of others in the compilation of their data, and appear to have been reluctant to omit traces mapped by others even though the traces lacked good evidence of Holocene activity. Consulting reports by Woodward-Clyde (1978) and Earth Science Associates (1977b) have demonstrated that active faults can be found in this area although they may not be found precisely where published literature shows them to be. Because of the density of urban development and its modification of the landscape, the interpretation of aerial photographs (especially old photos) appears to be the most useful tool available for a regional study such as this (except where fault creep is found). However, even if the interpreters are highly skilled, the actual location of an active fault may differ by a couple hundred feet from the feature delineated.

North of the Berkeley Hills, workers have clearly and conclusively documented fault creep. The middle segment (see item 6 above) does have a fairly well-defined, relatively narrow zone of features that probably are due to recent faulting; these have been delineated by Herd (1978) and Smith (this report). Other traces of the Hayward mapped by Case (1963) and subsequent workers lack good evidence of a through-going, recently active fault. The Wildcat fault also does not appear to be active in this area.

Along the southern segment of the Hayward fault, the geomorphic features indicative of recent faulting are less well-defined. Field checking has shown that urban improvements are commonly distressed as a result of downslope movement. Discerning whether a geomorphic feature, a broken curb, etc., or even a plane of displacement (e.g., identified in a trench) is landslide caused (or modified) or fault caused may be virtually impossible in the study of individual parcels of land. Indeed, it may well be that the landslides are moving downslope at a rate sufficient that creeping faults cannot propogate to the surface through the landslide mass. It may be that the "true" active trace of the Hayward in this area will only be identified after the next major fault rupture event.

9. Recommendations.

The Special Studies Zones along the Hayward fault should be revised, using the work of Herd (1978) and Smith (this report) as the primary sources of fault data. The SSZ's should be drawn such that all fault-produced topography shown by these two references are included in the zone. All soft data (e.g., tonal lineaments, breaks in slope) should necessarily be included in the zone only if they are aligned with more definitive features. Well-documented creep localities should be identified on the map (see Figure 7 for recommended version).

All traces shown on the 1974 Special Studies Zones maps of the Richmond and Mare Island quadrangle that do not coincide with the above described traces should be deleted, including the Wildcat fault of Bishop and the Case and Louderback traces of Radbruch (1968).

10. Principal investigator; date.

Theodore C. Smith

THEODORE C. SMITH
Associate Geologist
RG 3445, CEG 1029
November 5, 1980

TCS/map

I concur with the recommendations to revise the existing SSZ maps, generally as shown on Fig. 7.
EWH
12/29/80

note: Reproducibles for Figs. 2A, 2B, 3, 6 & 7 in A-P Plan-file.